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FOR NOVEL PRODUCT:

LITERATURE REVIEW

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Sika Gbègbèlègbè Dofonsou

James Lowenberg-DeBoer

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by
Sika Gbègbèlègbè Dofonsou and James Lowenberg-DeBoer
Dept. of Agricultural Economics, Purdue University
West Lafayette, Indiana 47907-2056
sgbegbel@purdue.edu; lowenbej@purdue.edu
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Abstract

This paper provides a critical review of the literature on non-market valuation methods to estimate the welfare impact of novel products; it is the first study to assess both observed data- and perception-based methods as non-market valuation methods. Observed data-based methods include budgets, regression, mathematical programming, and simulation. Perceptions-based methods include the contingent valuation method, choice-based conjoint analysis and experimental methods.

Findings imply that the preferred observed data-based method to estimate the ex ante economic impact of a new technology on the welfare of the farm household is a combination of simulation and mathematical programming. The preferred perception-based method for estimating the ex ante impact of a novel product on the welfare of an economic agent is represented by experimental methods.

Findings also imply that observed-data based methods and more specifically mathematical programming are more popular for estimating the ex ante farm-level economic impact of a new technology. On the other hand, perception-based methods are more popular for estimating the economic impact of a novel product for consumers.

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JEL Codes: B0, B4, C0, C6, R2

Introduction

Ex ante analyses are necessary to estimate the economic impact of novel products on producers and consumers. The ex ante assessment of a new technology is undertaken with non-market valuation methods which can be divided into two groups:

- Observed data-based methods: methods based on observed biological relationships, economic data, and assumptions about stakeholder objectives; and
- Perception-based methods: methods which elicit opinions about potential value of innovations from the expected stakeholders

The observed data-based methods use budgets, regression, mathematical programming, and simulation. The perception-based methods include contingent valuation, choice-based conjoint analysis, and experimental methods. The hedonic price, travel cost, and replacement cost methods are also categorized as non-market valuation methods, but they cannot be used to undertake ex-ante analyses because they all imply that the non-marketed goods/services must exist and must be consumed. These three methods also involve using market prices to estimate the value of non-marketed factors. Similarly, on-farm trials which also provide observations for perception-based analysis can also be used for ex ante analyses, but only when non-marketed products exist.

The next section focuses on how observed data- and perception-based methods have so far been used in the economic literature to estimate the farm level ex ante impact of a new technology. In section 3, the discussion relates to studies that have been used observed data- and perception-based methods to estimate the ex ante impact of a novel product on consumer welfare. Section 4 is the conclusion.

Farm Level Impact of New Technology

This section discusses how observed data- and perception-based methods have so far been used to estimate the ex ante farm level impact of a new technology. The discussion ends with the identification of the current shortfalls in the economic literature associated with using observed data- and perception-based methods for farm level ex ante impact assessment of a new technology.

The Methods Involving Observed Biological and Economic Data

Budget analysis can quickly provide credible and useful results with sparse data and modest expertise. However, the method tends to lack credibility with client when the analysis involves risk or a large variety of input-output combinations (Lowenberg-DeBoer, et al, 1989). The disadvantages of budget analysis can be outlined with the study by Doupé and Lymbery (2002) who used budget analysis to estimate the impact of a genetically modified fish species on two Australian fish production systems. Their analysis dealt with the random character of fish growth rate, prices, and fish survival rates by undertaking sensitivity analysis with a range of values for these three variables. The conclusions by Doupé and Lymbery are unlikely to be accurate since fish growth rate, prices, and fish survival vary simultaneously in the real world but are varied one after the other in the sensitivity analysis. So that the impact of one factor cannot be accurately estimated with the model used by Doupé and Lymbery! Typically budget analysis uses sensitivity testing to examine risk, but the interpretation of the results is highly subjective. It is difficult to incorporate probabilities and utility function information (i.e. risk aversion levels) into budget sensitivity testing (Lowenberg-DeBoer, et al, 1989). If there are many observations on the results of using a technology, it may be possible to budget out benefits for each observation and estimate distributions which can be compared using stochastic dominance rules. For example, Hien et al (1997) use on-farm trial data to estimate distributions of yield and net returns in comparing alternative phosphate fertilizer sources in Burkina Faso. Similarly, the analysis by Doupé and Lymbery involved only one type of new technology; it would have been more cumbersome had the authors considered a larger number of input-output combinations (Lowenberg-DeBoer et al., 1989).

Regression analysis, compared with budget analysis, requires more dense data which must also satisfy specific assumptions. However, the required expertise for regression analysis is relatively modest due to user-friendly software (Lowenberg-DeBoer, et al, 1989). A study by Shively (1999) can be used to illustrate the characteristics of regression analysis. Shively (1999) uses both stochastic dominance and regression analysis to analyze the impact of a new soil conservation technique on low-income farms in Philippines. The study demonstrates that regression data need to satisfy the assumptions underlying regression techniques to provide credible results. Similarly, the data used by Shively (1999) may not satisfy the assumption of continuous response function underlying the use of regression analysis, and this may explain why some of the econometric results derived by Shively (1999) are not statistically credible.

Mathematical programming, contrary to budget and regression analysis, can use sparse data to evaluate technology within complex farming systems. However, mathematical programming requires a relatively high level of expertise (Lowenberg-DeBoer, et al, 1989). Similarly, the required time to obtain results varies from moderate to high. For example, Preckel, Harrington, and Dubman (2003) use mathematical programming to estimate how an adverse consumer reaction to GM grain could affect U.S. agricultural production sector. The authors derive a detailed mathematical model which supposedly captures the processes linking the production and uses of grains from the perspective of US grain farmers. Then, they use the model to determine optimal production decisions under the status quo as well as under a decrease in the demand for U.S. GM grains. They validate their model by showing that optimal production decisions under the status quo resemble collected sparse data which reflect production activities in the US agricultural sector in 1998. Their conclusions seem to encompass all grain production aspects since they range from the impact of an adverse consumer reaction on grain production, agricultural prices, to the GM content of inputs involved in both grain and livestock production. The authors conclude that GM grains would be shifted from export to domestic uses if U.S. trading partners were reluctant to accept GM grains; similarly, GM grains would more likely be diverted into the domestic livestock sector if both domestic and foreign demands for GM grains were to fall.

Bio-economic simulation is very useful when the assessment of the new technology must be considered in the context of a very complex biological system. However, the method requires detailed data on biophysical processes. Similarly, the required expertise for bio-economic simulation varies from modest to very high. The main downfall with bio-economic simulation is that the calculations are very complex and hard to explain to non-specialists; therefore, the method is perceived by most non-scientific clients as a black box. However, bio-economic simulation models are easier to validate compared to mathematical programming models largely because biophysical processes are often easier to explain than human behavior (Lowenberg-DeBoer, et al, 1989). The study by Archer and Gesch (2003) demonstrates that biophysical simulation can provide results from complex biophysical systems. The authors used a biophysical simulation model to estimate the impact of a new technology on crop yields and availability of field days for various planting periods, crop varieties, tillage systems, and soils. They also attempted to develop a mathematical programming model to capture the problem of the representative farmer in Stevens County, Minnesota. This problem broadly consists in maximizing expected net profits given a production function and uncertain weather conditions. The authors conclude that polymer-coated seed could increase net returns by increasing yields when planting is early, reducing yield loss when planting is delayed, and by increasing the use of varieties adapted for longer season. Stochastic dominance can also be used to provide an economic interpretation to the cumbersome simulation results.

Table 2.1 summarizes the results from comparing the observed observed data-based methods with criteria relating to data, expertise, and time requirements as well as credibility and usefulness of results (Lowenberg-DeBoer et al., 1989). The information in Table 2.1 implies that a combination of simulation and mathematical programming would be most appropriate to estimate individual or regional impacts of new agricultural technologies in developing countries. Simulation is the most appropriate observed observed data-based method to obtain accurate observations on the impact of a new technology on biophysical variables such as crop yields, while mathematical programming is most appropriate for modeling and solving the complex economic problems of decision-makers. Since farm households in developing countries tend to face complex economic problems and biophysical environments, a combination of mathematical programming and simulation would be most appropriate for modeling and solving the problem of these households.

However, when well developed simulation models do not exist, mathematical programming becomes the sole available observed data-method to estimate the ex ante farm level economic impact of a novel product.

Table 2.1: Comparison among Ex-Ante Technology Assessment Methods Based on Biological and Economic Data

Factors	Budget analysis	Regression analysis	Mathematical programming	Bio-economic Simulation
Required data	• Can use all types of data including trials, surveys & expert opinion. • Makes use of sparse data	• Requires data that fulfill statistical assumptions • Pooling data from disparate sources sometimes difficult	• Can use all types of data including trials, surveys & expert opinion • Makes use of sparse data	• Can use all types of data including surveys, trials and expert opinion • Requires detailed data on the biophysical process
Required expertise	• Modest	• Relatively modest thanks to availability of easy to use software	• Relatively high	• Modest if a simulation model already exists. Very high if model development required. • Cooperation among social and biological researchers is essential
Required time to results	• Quick	• Moderate	• Moderate to long depending on whether there are previous models to start from.	• Very long if model development required
Credibility of results with clients	• Credible with many clients because easy to understand – short chain of reasoning from data to conclusions • More likely to provide inaccurate results when analysis involves risk or a large variety of input-output combinations	• Relatively short chain of reasoning – client can often see the role of the original data in the results • Credibility depends upon statistical results • More likely to provide inaccurate results when functional form is inappropriate, or when data violates statistical assumptions	• Complex chain of reasoning. May be considered a black box by some clients, but link to budgeting provides some client credibility • Validation tests results determine credibility • Problems often occur when system linkages not well modeled.	• Complex chain of reasoning – will be considered a black box by most clients. • Validation tests results determine credibility • Often hard to organize and summarize results.
Usefulness of results	• Quite useful to decision-makers	• Useful for economic analysis of continuous response relationships.	• Especially useful when the technology must be considered as part of a farming system.	• Especially useful when technology must be considered in the context of a complex biological system

Literature Review on the Impact of a New Technology on the Welfare of the Farm Household – Mathematical Programming

Mathematical programming has proved useful for modeling risk in the problem of the farm household and estimate risk impact. Farm income and therefore utility is subject to variation due to all the risks inherent to agricultural production. Therefore, each farm plan may be perceived as being associated with a probability distribution for agricultural income. With risky outcomes, the farmer aims at ranking farm plans and selecting the one that best fits her preferences. Various decision rules derived from economic theory have been developed to rank income distributions. The most established theory on decision rules is the expected utility theory which predicts that x1 would be preferred to x2 if the expected utility over all potential outcomes is larger with x1 than with x2 (Hazell and Norton, 1986).

When the utility function is of the exponential form, the mean-variance analysis which involves mathematical programming models can be used to derive a set of efficient farm plans, with each farm plan having the smallest variance for the associated expected income level, E. The degree of risk aversion of the farmer is then used to identify the optimal farm plan (s) for the farmer, as dictated by the expected utility theory. Quadratic programming and linear programming methods such as the ones involving the MOTAD model can also be used to identify the set of efficient farm plans obtained with mean-variance analysis. The mean-standard deviation analysis also provides the same set of efficient farms as the mean-variance analysis. With the mean-standard deviation analysis, the set of efficient farm plans includes farm plans with the smallest standard deviation for the associated expected income (Hazell and Norton, 1986).

Apart from the expected utility theory, other premises exist which can also be used to rank income distributions. These methods include game theory, and theories based on safety-first models. The most common decision criteria rules which are based on game theory are the Wald maximin and Savage regret. Safety-first models are most appropriate when the risk of tragedy is large, and they imply that the farm must be able to generate the income necessary to meet fixed costs and the family living costs every year. Safety-first models include Roy's safety-first model, Low's safety-first model, target MOTAD, and the focus-loss model (Hazell and Norton, 1986).

When the constraint set includes risk, dynamic stochastic programming (DSP) and chance-constrained models can be used to rank risky outcomes (Hazell and Norton, 1986). DSP models are also appropriate in situations where optimal decision making is sequential, adaptive and subject to risk.

Hazell and Norton also demonstrate that the goal of small scale farmers in developing countries may not solely consists in maximizing agricultural income, and may therefore also include the desire to provide adequate food to the household as well as the desire for more leisure. In other words, the problem of small scale farmers in developing countries is likely to correspond to the farm household problem which combines three sub-problems relating to production, consumption, and labor. The authors then explain that when markets are competitive, the household's problem is separable, meaning that it can be solved with a two-stage decision process. In the first stage, the household would aim at identifying the input levels maximizing agricultural income; then, given income and market wage, this household would aim at solving its utility maximization problem, with utility being defined over both consumption goods and leisure (Hazell and Norton, 1986).

When there is market failure, the household's problem is no longer separable, but the authors claim that in these situations, it may be appropriate to assume that the household undertakes sequential decisions in the sense that it aims at maximizing agricultural income and then allocating optimal income so as to maximize utility. However, the latter approach involves the observance of additional assumptions about leisure preferences (Hazell and Norton, 1986).

An alternative way of analyzing the household problem is to assume that this household faces multiple goals. One way of solving a problem involving multiple goals is to maximize/minimize one goal and specify the others as inequality constraints. The other way consists in applying goal programming which involves defining a target for each goal and then attempting to minimize deviations from this target (Hazell and Norton, 1986).

Various empirical studies use mathematical programming to estimate the impact of new agricultural technology in a developing country. Adesina, Abbott, and Sanders (1988) use a MOTAD model to undertake the ex-ante appraisal of a new agricultural technology package involving fertilizer use for Niger. Their modeling results indicate that highly risk-averse farmers may adopt fertilization on very limited crop area; for farmers with lower risk aversion, cash constraints and seasonal weeding time labour constraints discourage higher fertilizer use (Adesina, Abbott, Sanders, 1988).

Shapiro (1990) uses discrete stochastic sequential programming (DSSP) to undertake the ex ante evaluation of new technology under uncertainty in two different Niger agricultural systems, the River system and the Dryland system. The new technology consists of improved cultivars and fertilizer use. Shapiro notes that the model derived by Adesina only considered income creation through crop production and ignored alternative sources of income such as livestock production. For both the River and the Dryland systems, Shapiro concludes that liquidity availability is not a constraint for the adoption of new technology. Such a result is contrary to the one derived by Adesina, Abbott, and Sanders. It therefore appears as if the failure to consider all income sources in the farm household model biased the results derived by Adesina, Abbott, and Sanders. However, the results derived by Shapiro may also be biased because they ignore risk aversion and also because they do not include crop rotation systems (Shapiro, 1990; Adesina, Abbott, Sanders, 1988).

Ensink (1989) also uses a variant of the MOTAD model to appraise some new technology consisting of improved varieties of sorghum cultivars in Southern Niger. He models the problem of the farm household with the target MOTAD model which is more consistent with economic theory compared with the mean variance model or the MOTAD model itself. He points out that farm households in the study are involved in both crop and livestock production, but he bases his model entirely on crop production. Therefore, his empirical results may be biased since he ignores the role of livestock production as a source of income for the farm household.

Studies focusing on the adoption of improved cowpea cultivars relate to the intensification process involved in agricultural production, the potential for the adoption of alternative crops to cowpea in Southern Niger, and the evaluation of currency devaluation on the adoption of improved cowpea cultivars in the Malian Sudanian region (Abdoulaye, 1995; Aduayom, 2003; Coulibaly, 2003).

Abdoulaye and Lowenberg-DeBoer (2000) undertook a study to identify the intensification process involved in agricultural production in southern Niger. The goal of the study is achieved with a whole farm modeling methodology which involve linear programming and which includes crop production, livestock production and non-agricultural activities as sources of income for the farm household. Crops include cowpea, millet, sorghum, with cowpea being considered as cash crop. Both weather risk and food availability risk are considered in the model and the objective of the farm household is assumed to consist in expected income maximization. The results suggest that agricultural intensification starts with traditional inputs and eventually leads to the use of modern inputs including improved cultivars, fertilizer, and pesticide in southern Niger. They also suggest that the high opportunity cost of capital is the key element driving the intensification process: farmers tend to start with traditional instead of modern intensification due to the lower capital requirement needed for traditional intensification (Abdoulaye and Lowenberg-DeBoer, 2000). The authors use the results of the study to recommend that development effort should start with the intensification of traditional cropping strategies rather than with modern crop inputs (Abdoulaye and Lowenberg-DeBoer, 2000).

The results presented in the study by Abdoulaye and Lowenberg-DeBoer (2000) may be biased because their empirical model assumes that weather risk is reflected only by variability on the timing at which rain onset occurs. Various studies suggest that both rain onset and intensity vary throughout the cropping season and this is how weather risk affects agricultural income (Shapiro, 1990; Coulibaly, 1995). The approach used by Abdoulaye and Lowenberg-DeBoer (2000) might explain why their model does not well predict the mono-cropping activities of the farm households using animal traction in agricultural production for the validation tests (Abdoulaye and Lowenberg-DeBoer, 2000).

Aduayom (2003) evaluates the potential for the adoption of mucuna over cowpea in Southwestern Niger. Linear programming is used to model the production and consumption behaviors of farm households in Southern Niger and the goal of the linear programming model consists in maximizing expected agricultural income. Mucuna production activities are then incorporated into the model to identify the elements influencing mucuna adoption (Aduayom, 2003). The results imply that farmers would adopt mucuna when it outperforms cowpea by at least 10% for improved soil fertility. Similarly, limitations on labor availability appear to incite farmers to adopt mucuna over cowpea. The results from the model also imply that mucuna is not superior to cowpea as forage; therefore, farmers in southern Niger are less likely to adopt mucuna over cowpea for forage production (Aduayom, 2003). The linear programming model incorporates crop activities, livestock activities, and non-agricultural activities as sources of income. However, this model is based on the assumption implying that weather risk is only reflected by variability on rain onset and not on variability on both rain onset and intensity throughout the season, so that the empirical results derived by Aduayom could be biased (Aduayom, 2003).

Coulibaly (1995) evaluates the impact of devaluation on the profitability of agricultural technologies in two agroecological zones in Mali, the Sudanian and the Sudano-Guinean zones. The technologies include inorganic and manure fertilization, combined with improved cultivars of sorghum, cotton, maize, millet, and groundnut for the Sudano-Guinean region; they include soil fertilisation and land preparation techniques combined with improved cultivars of millet, sorghum, groundnut and cowpeas for the Sudanian region.

The whole farm modeling method based on the expected utility theory is used to achieve the goal of the study. The model implies that crop production is the sole source of income for the farm household; it does not incorporate livestock production and non-agricultural activities as direct sources of income for the farm household. Weather risk is taken into account in the model. However, the latter does not consider that weather risk incites farmers to undertake sequential and adaptive decisions. These omissions may bias the results derived by Coulibaly even if validation tests suggest that the model predicts well the crop production decisions of the farm households in the two Malian agro-ecological zones (Coulibaly, 1995). As explained previously, Adesina, Abbott and Sanders (1988) derived biased conclusions even if validation tests suggested that their farm programming model was consistent with observed behaviour.

The results from the study imply that the devaluation limits the adoption of improved cultivars in the short run in both zones. However, technological change is likely to be more prominent in the long run in the Sudanian region, compared to the Sudano-Guinean region. Similarly, the adoption of new agricultural technologies when associated with some policy measures that facilitate capital access can substantially increase farm incomes (Coulibaly, 1995).

Among all previous studies, only the ones by Adesina, Abbott, and Sanders (1988), Ensink (1989), and Coulibaly (1995) involve mathematical programming models based on the expected utility theory which predicts that farm plan x1 is preferred to x2 if the expected utility defined over all potential outcomes is greater with x1 compared with x2 (Hazell and Norton, 1986). In all the other studies, a new technology is assumed beneficial if expected farm income is higher with the new technology than without. The criterion consisting in comparing expected profits with and without new technology to determine if the latter is beneficial is based on two assumptions, one implying that the farm household is risk neutral, and the other implying that all markets are competitive so that the household problem can be broken down into two sub-problems to be solved sequentially, one on production and the other on consumption. The production sub-problem consists in determining production activities that maximize farm income subject to production constraints. In this sub-problem, farm income is maximized independently of consumption decisions. The consumption sub-problem consists in determining consumption activities which maximize household's welfare subject to consumption constraints incorporating the optimal farm income (Hazell and Norton, 1986). The assumptions of perfect markets and risk-neutrality imply that the expected welfare of the farm household increases with expected income. Therefore, no utility function is needed to estimate the impact of a new technology from the household's perspective.

However, the assumption of risk-neutrality is unlikely to be realistic since numerous empirical studies suggest that farmers tend to behave in risk-averse ways (Hazell and Norton, 1986). Coulibaly (1995) assumed that the negative exponential utility function would best capture households' preferences, and validation results suggested that moderate risk-averse behaviour is more appropriate for cowpea producers in the Sudano-Guinea region of Mali. The target MOTAD model derived by Ensink (1989) implies that optimal activities in the base model are similar to observed activities for the risk-averse farmer. The author does not compare the base results from the target MOTAD with observed practices for risk-averse farmers, so that it is difficult to determine if these base results are reflective of the activities undertaken by risk-averse farmers in Konni region in Niger.

Sidibe (2000) used both a lexicographic indirect utility function and the traditional mean variance model to capture the consumption preferences of farm households, and aim at estimating the impact of new technology and structural adjustment policies on households' welfare in the peanut basin of Senegal. The lexicographic utility function used in the study by Sidibe (2000) implies that the priorities of the farm household are in decreasing order of importance: achieve a minimum income level; secure basic food needs; and maximize profits. Validation tests suggested that the lexicographic indirect utility function was more appropriate for capturing the preferences of farm households in both the Southeastern and Central peanut basins in Senegal. The empirical results related to the lexicographic utility function imply that new technologies would be beneficial to farm households. It is important to note though that if the lexicographic utility function compared to the common continuous utility function can better capture the preferences of the farm household at a given point in time, it is usually not flexible enough to explain the mechanism of decision-making.

One issue with the studies involving models based on the expected utility theory relates to agricultural income. None of these studies considered all the sources of agricultural income in their model and therefore they all could have produced biased results.

Most of the previous studies were related to Niger. However, mathematical programming has also been used to estimate economic impacts in other countries. Roth (1986) aimed at estimating the impact of policies developed by the IMF for Burkina Faso and consisting of eliminating food aid, raising commodity prices, and reducing fertilizer subsidies. The economic framework used in his analysis involved producer, consumer, international trade, private market equilibrium, and public market equilibrium components. The household model was used to encompass the consumer and producer problems in Burkina Faso, with the problem of the farm household assumed to be separable. Risk was not considered in the analysis and this could have lead to biased results. There are numerous other studies aimed at estimating the economic impact of new technologies for farmers in Ethiopia, Mali, Mozambique, Malawi, Cameroon, Zambia, and Southern Africa.

A paper by Nhantumbo and Kowero (2001) aims at presenting a methodological framework to estimate model aims at explaining the effects of macro-economic policies on farm households and middlemen between farmers and consumers in poor regions composed of woodland. The model developed in this paper was not empirically tested, so that it is difficult to determine if it assumptions are valid. One central assumption in this model implies that the goal of profit maximization distorts the reality of the typical household and that this household rather has various priorities of differing importance, so that goal programming is better suited for explaining the problem of this household. However, the authors do not provide sufficient argument to support their claim. Having goals to meet in near future is not necessarily contradictory with the notion implying that household wants to maximize expected profits, i.e. long term average profits.

Holden (1993) also uses goal programming to analyze the evolution of farming systems in Zambia. The theoretical model used for the study implies that the utility of the household essentially depends on both income and family labour and that equilibrium is achieved when the marginal rate of technical substitution between family labour and income equals the marginal productivity of labour. Holden then translates the problem of the household into a goal programming model and attempts to explain the evolution of farming systems in Zambia in relation to the introduction of three technologies cassava, maize, and fertilizer. The results from his model imply that cassava replaced millet among Zambian farms because it led to a reduction of about 40% in the amount of labour needed to grow food to meet basic needs. He also explains that the technology basket composed of maize and fertilizer probably reduced the practice of slash-and-burn cultivation, but could not replace it entirely because this technology basket alone is not sufficient to incite farmers to abandon the practice of slash-and-burn.

One shortfall in the model used by Holden (1993) relates to the omission of important variables affecting indirect utility. The author assumes that income and labour are the only variables affecting utility. Other major variables that could impact the indirect utility function of the household include commodity prices and variables expressing the consumption and production characteristics of the household. Moreover, Holden does not also validate his model, so that that it becomes very difficult to find out whether his model can really provide accurate insights on the evolution of farming systems in Zambia.

Yigezu (2005) also attempts to use a goal programming model to assess the impact of three technologies on the welfare of farm households in the region of Qobo in Ethiopia. He concludes that nutritional intakes of farm households in this region would significantly increase, were these households to simultaneously adopt the three technologies and also have access to inventory credit. The three technologies include *Striga* resistant sorghum varieties, fertilizers, and water storage schemes. Yigezu (2005) implies that the priorities of the typical household in Qobo are in order of importance: debt reimbursement, food security and then maximization of residual profit. However, the mathematical programming model used in the study is not a goal programming model since it does not reflect that the household puts differing levels of importance on its goals. This model is rather a LP model implying that the household views its three priorities as being equally important. The LP model used in this study was empirically tested and, based on results from validation tests, does capture quite well the decision-making process of the typical household in the Qobo area.

A study by Thangata Hildebrand and Gladwin (2002) uses a Linear Programming (LP) model to estimate the potential for improved fallows to be adopted by small-scale farmers in the region of Kasungu, Malawi. The results imply that the likelihood of a farm household adopting improved fallows increases with the amount of land and labour available on this farm. However, these results are questionable since the LP model used for the study does not include the major risks involved in generating agricultural income in Malawi. The dynamic ethnographic LP model used in this study involves 10 years of economic activities by the farm household; it is ethnographic because it includes quantified ethnographic data on farmers' behavior in the surveyed region. Based on this LP model, the household aims at maximizing household income or food production subject to constraints on cash, labor and land, after meeting home consumption requirements. Risk is not considered in this model even though agricultural production in Malawi takes place in an environment characterized by uncertainty on weather, prices, transportation, storage, etc. Therefore, the results and even the trends derived from the model used in this study are very likely to be biased. Moreover, the authors do not attempt to validate their model, so that their results are even more questionable.

In summary, there are numerous empirical studies that use mathematical programming to undertake the farm level ex ante analysis of a new agricultural technology in a developing country. However, there is no study which involves a model that considers all the sources of agricultural income and also allows the farm household to be risk-averse. Previous studies which incorporated the possibility of risk-aversion tended not to consider all the sources of agricultural income, while the studies which considered all the sources of agricultural income tended to impose risk-neutral behavior on the farm household.

The Methods Involving Perceived Biological and Economic Relationships

The contingent valuation and choice-based conjoint analysis are stated preference methods because they are based on intended behavior. Experimental methods are somewhere in between stated and revealed preference methods: they relate to revealed preference methods because they involve real markets; they relate to stated preference methods because they involve creating markets and therefore carry drawbacks resembling the ones related to stated preference methods (Fix and Loomis, 1998; Lusk and Hudson, 2004). Revealed preference methods are based on actual choices and include the hedonic price, travel cost, and replacement cost methods.

The contingent valuation and contingent choice methods circumvent the absence of markets for environmental goods by presenting consumers with hypothetical markets in which they have the opportunity to pay for the good in question. The contingent valuation method consists in estimating the benefits/costs related to non-marketed commodities by asking individuals to state their WTP or WAC based on hypothetical scenarios. The contingent choice method, which is also based on hypothetical scenarios, consists in estimating the benefits/cost of non-marketed commodities by asking people to make tradeoffs between alternative products where the products are defined by several attributes, such as price and quality (Freeman, 1993).

One important issue related to either contingent valuation method or choice-based conjoint analysis consists in the ability of the survey instrument to provide a stated WTP/WTA identical to the true WTP/WTA. Three types of errors would cause the estimated WTP/WTA to differ from the true WTP/WTA: random error process which causes what some call hypothetical bias, non-response process, and systematic error process. Random error process occurs when the scenarios related to the valuation methods do not seem familiar and believable. The impact from this error process can be alleviated with some increase in the sample size and improvement in the sample design. The non-response process can cause two types of bias: sample non-response bias, and item non-response bias. Sample non-response bias occurs when the population characteristics related to some or all the variables are unknown. Item non-response bias occurs when a variable, in the survey instrument, affects both the WTP of the respondent and the probability of a respondent participating in a survey (Freeman, 1993).

Systematic error process includes scenario misspecification, implied value cues, and incentives for misrepresentation. In regards to scenario misspecification, the stated WTP could be biased if the respondent does not understand the questions and the information provided by the investigator. Implied values cues would arise, and would also bias the stated WTP if the respondent is not clear about his/her preferences and seeks clues regarding the “correct” choice or value from the information supplied as part of the scenario specification. Incentives for misrepresentation also generate hypothetical bias and occur if the scenario specification and the framework for eliciting values are not incentive-compatible. If the respondent believes his/her responses cannot have an effect on the level of provision of a good, he/she has an incentive to understate the true value of the good. On the other hand, if a respondent believes his/her responses have an effect on the level of provision of the good, he/she has an incentive to bid high if he/she prefers more of the good, or bid low if he/she prefers less of the good (Freeman, 1993).

The contingent valuation method is more flexible than any other non-market valuation technique involving ‘perceived’ economic and biological relationships because it can be applied in relation to a wider variety of non-marketed goods/services. Qaim and de Janvry (2003) use the contingent valuation method to estimate WTP for Bt cotton seed so as to analyse the impact of the 2001 Bt cotton pricing policy on farm-level benefits and on the profits of Bt cotton seed suppliers in Argentina. The results from their empirical study implied that the actual market price for Bt cotton is higher than both farmers’ average WTP for Bt cotton seed and the price which would maximize profits of the seed suppliers. The structure of the survey instrument consisted in direct interviews of respondents with double dichotomous choice questions. The authors did not use formal statistical tests to measure the accuracy of their empirical results; they rather seem to have attempted to prevent bias at the source through a careful elaboration of the survey instrument (Qaim and De Janvry, 2003).

Baidu-Forson et al. (1997) use conjoint analysis to identify groundnut traits which significantly contribute to increasing the farmers' utility so as to facilitate the development of improved groundnut varieties, using Niger as a case study. The authors conclude that leaf spot disease resistance, improved pod yield, and short crop cycle are statistically significant and positively related to farmers' utility so that improved groundnut varieties should be developed based on these latter characteristics. Here too, the authors do not undertake formal econometric tests to measure the accuracy of their results and rather attempt to prevent bias through a careful elaboration of the survey instrument (Baidu-Forson et al., 1997). The contingent choice method may provide inaccurate results if the sample size is not increased as the number of attributes is increased. Furthermore, the translation, into dollar values, of the answers gathered through the contingent choice method, may lead to greater uncertainty in the actual value that is placed on the good or service of interest (King and Mazotta, 2008).

However, conjoint analysis has several advantages over contingent valuation techniques: it is consistent with the theory of utility maximization based on Lancaster; it closely imitates shopping decision-making processes; can be used to study tradeoffs between product attributes; can be used to approximate cross-price elasticities between products. Another advantage of the CBC framework is that hypothetical responses to CBC questions have been found to be similar to revealed preferences (Lusk and Hudson, 2004).

Experimental auctions consist in estimating the benefits/costs related to a non-marketed commodity by setting up real market situations in which individuals are incited to reveal their WTP and/or WTA. Experimental auctions aiming at estimating WTP and WTA are usually classified in two categories. One category includes the auctions where individuals are invited to bid to exchange an endowed commodity for a novel one. The other category includes the auctions where individuals bid on several competing commodities.

Most empirical studies using experimental auctions for production analysis usually aim at verifying micro-economic concepts on firms' behavior relative to game theory. So, there are virtually no empirical studies that aim at estimating the impact of a non-marketed production input on producers' welfare, nor are there studies that estimate producers' demand for a non-marketed production input. There are several advantages to using experimental auctions instead of contingent valuation or choice-based conjoint analysis to elicit consumer WTP for novel goods or services: the shape of the market demand curve is known with experimental auctions; experimental auctions provide WTP/WTA values that are more likely to be true WTP/WTA because gathered in real market settings. The major drawback to experimental auctions consists in bias which would cause estimated WTP/WTA to differ from true WTP/WTA. However, bias in experimental auctions may be mitigated if experiments occur in a field instead of lab setting. Estimated bids in experimental auctions may be biased because:

- Respondents must be financially rewarded to attend the experiments: the higher the financial reward, the higher bids tend to be; bias may also occur because the sample study is less likely to be representative of the population with the presence of financial reward
- Experiment settings omit important factors and therefore differ from actual markets settings
- Bidder values may be or become affiliated from one experiment to the other and this degrades the incentive compatibility of an auction
- Zero-bidding may occur not because this is the true valuation but simply because individuals are not interested in the commodity

Table 2.2 summarizes the comparison between the contingent valuation, choice-based conjoint analysis, and experimental methods based on the same criteria used in Table 2.1. The information in Table 2.2 implies that experimental auctions may be easier to use for estimating the ex-ante impact of a new technology on farmers' welfare. However, experimental auctions can only be conducted when non-marketed commodities are available. In the absence of these elements, the contingent valuation and/or choice-based conjoint analysis methods become most appropriate for estimating the impact of new agricultural technologies on farmers' welfare.

Table 2.2: Comparison among Ex-Ante Technology Assessment Methods Based on 'Perceived' Biological and Economic Relationships

Method	Required data	Required expertise	Required time to results	Credibility of results with clients	Usefulness of results
Contingent valuation method (CVM)	• Requires WTP/WTA data provided by respondents • Requires data that fulfill statistical and economic assumptions	Relatively simple	Quick to moderate	• Relatively short chain of reasoning • Credibility partially depends upon statistical results • Tends to provide inaccurate results due to presence of hypothetical bias, but latter may be minimized (cheap talk, etc.) • Most flexible method: may be used to analyze wide range of non-marketed commodities	Useful when product does not exist
Choice-based conjoint analysis (CBC)	• Requires data provided by respondents • Requires data that fulfill statistical and economic assumptions	Relatively high	Quick to moderate	• Relatively short chain of reasoning • Credibility partially depends upon statistical results • Tends to provide inaccurate results due to presence of hypothetical bias, but latter may be minimized • Preferable to contingent valuation for providing more economically accurate results but may be more difficult to implement	Useful when product does not exist
Experimental auctions	• Requires bids provided by respondents • No econometric analysis is needed to derive the WTP curve	Relatively high	Quick	• Relatively short chain of reasoning • Provides inaccurate results when there is bias, but latter can be prevented • More difficult to estimate cross-price effects compared with choice-based conjoint analysis method	Useful when actual non-marketed product exist

Source: Fix and Loomis, 1998; Lusk and Hudson, 2004; Qaim and De Janvry, 2003; Baidu-Forson et al., 1997

Literature Review on the Impact of New Technology on the Welfare of the Farm Household – Contingent Valuation method and Conjoint Analysis

The studies that use contingent valuation or conjoint analysis to estimate the impact of a new agricultural technology on farmers' welfare relate to the adoption of Bt cotton seed, Identity Preserved (IP) crops, and improved groundnut varieties. Quaim and De Janvry (2003) used the contingent valuation method to estimate an optimal price for Bt cotton seed in Argentina. Hudson and Jones (2001) use the contingent valuation method to analyze farmers' willingness to plant Identity Preserved (IP) crops in Mississippi. Baidu-Forson et al. (1997) used conjoint analysis to identify significant attributes affecting the willingness to adopt groundnut varieties in Niger. Most of the other applications of the contingent valuation method on farming issues relate to the adoption of environmentally friendly management practices. The other agricultural applications of conjoint analysis mainly relate to consumer choices and farm diversification.

Quaim and De Janvry (2003) attempt to minimize bias with a careful elaboration of the survey instrument. The stated WTP gathered through their survey are likely to reflect a small level of non response bias because the study samples seem to be reflective of populations. The sample of Bt cotton adopters in the study correspond to about 60% of all adopters in Argentina. Similarly, a comparison between official and sample statistics implies that the sample study of non-adopters is reflective of the population of non-adopters in Argentina. The choice question used in the survey instrument, i.e. the double dichotomous choice question, provided boundaries to the stated WTP and is therefore likely to have generated bias through implied value cues. The authors do not provide the survey in their article so that it is difficult to better estimate the incidence of bias resulting from implied value cues. It is also almost impossible to estimate the incidence of bias resulting from scenario misspecification, incentives for misrepresentation, and random error process.

Hudson and Jones (2001) also attempt to minimise bias via a careful design of the survey instrument, but they also are unable to eliminate it. The structure of their survey instrument consisted in mailing a questionnaire to a representative sample of farmers and following-up respondents via telephone. The stated WTP values gathered through the survey are likely to reflect a low level of bias generated by scenario misspecification because the scenario in the survey is based on the referendum question format and is therefore likely to be easy to understand. Similarly, the incidence of bias resulting from the existence of incentives for misrepresentation is likely to be low, because people answering 'yes' or 'no' to a referendum question are likely to believe that the provision of the good/service will be based on the plurality voting rule and therefore have nothing to gain by biasing their answer. Furthermore, respondents are less likely to rely on the survey to seek their true WTA for planting IP crops; therefore, bias resulting from implied value cues is likely to be small. The incidence of bias resulting from random error process is likely to be low: the response rate for the survey was high, 61%, and the referendum question format is likely to have increased the ability of the survey to be familiar and believable. It is difficult to determine the incidence of non-response bias since the authors provide no information on the ability of the sample study to be representative of the population. Furthermore, the authors do not provide a copy of the survey so that it is difficult to assess more appropriately the incidence of bias.

Baidu-Forson et al. (1997) also attempt to correct bias via a careful design of the survey instrument. The response rate related to their study is 100%, but this does not inform on the incidence of non-response bias. The incidence of the bias resulting from systematic error process could have been large: respondents may have found the scenario too complex to understand; the information provided in the scenario could have biased the results for some confused respondents via implied value cues; similarly, the scenario could have provided some incentives for misrepresentation which would have also biased the results for some respondents. Also, the bias resulting from random error process could also have been large since respondents may have not found the scenario familiar and believable.

The careful design of the survey instrument is not the only method used to mitigate bias in stated WTP/WTA values. However, it appears to be the only method available to mitigate the bias resulting from systematic error process. Wheeler and Damania (2001) develop a method to test for the presence of bias resulting from incentives for misrepresentation, but propose no new solution to reduce the incidence of this bias.

Whitehead, Groothius, and Blomquist (1993) propose methods to test for the presence of both sample and item non-response biases. Their proposed test for sample non-response bias consists in comparing the characteristics of respondents and non-respondents in the sample related to the study; a difference in the results would imply that there is non-response sample bias and this can be corrected by using population means instead of sample means whenever possible. Their proposed test for item non-response bias consist in determining if correlation exist between error terms in equation explaining the probability of a respondent participating in the survey and the error in the equation explaining the WTP of respondents. They propose no new solution for mitigating the bias resulting from item non-response bias. Seung-Hoon and Hee-Jong (2001) also test for the presence of item non-response bias with the method used by Whitehead, Groothius, and Blomquist (1993) but they also propose no new solution to mitigate non-response bias.

To mitigate hypothetical bias, Bjornstad, Cummings, and Osborne (1997) develop a learning design which consists in undertaking an auction in which respondents can earn/spend real money and following the auction with the hypothetical experiment. Their empirical results suggest that the learning design related to the survey instrument involving the referendum choice format for the contingent valuation method is successful in eliminating hypothetical bias. Champ and Bishop (2001) propose using the certainty question to identify respondents responsible for hypothetical bias and adjusting in consequence the answers of these respondents. The main weakness of the method involving the certainty question is that it is difficult to isolate the respondents producing hypothetical bias without previous actual WTP/WTA results. List and Gallet (2001) suggest mitigating hypothetical bias by using more of some of elements relative to others. Their empirical results imply that hypothetical bias is greater with WTA studies, and therefore suggest that it is preferable to undertake WTP rather than WTA studies. Similarly, their study suggests that some choice question formats are preferable to others. The random nth price auctions appear to be preferable to Vickrey 2nd price auctions and open-ended choice questions. Similarly, 1st price auctions are preferable to open-ended elicitation schemes and dichotomous choice questions.

The calibration of stated WTP/WTA values to actual ones and the use of explicit warnings in the survey instrument were the initial methods used to mitigate hypothetical bias. The main drawback related to calibration factors is the fact that each one of them has to be determined for each study. Nape et al. (2003) explain that calibration factors vary with demographic characteristics, so that calibration factors should vary on a case by case basis. The most popular explicit warnings take the form of cheap talk which consists in explaining hypothetical bias so as to reduce its occurrence. Cheap talk, which is the current most popular method used to mitigate hypothetical bias, has been shown to provide WTP/WTA estimates similar to actual values. The main issue related to using cheap talk relates to the effectiveness of cheap talk in relation to respondent's knowledge and the choice question format. Lusk (2003) combines cheap talk with the contingent valuation method to mitigate hypothetical bias in the estimation of WTP for golden rice, some rice genetically modified to contain beta-carotene which is converted in the body into vitamin A. The empirical results from Lusk's study imply that cheap talk reduced or eliminated hypothetical bias for consumers who were not knowledgeable on genetic engineering, but had no impact for knowledgeable consumers. Brown, Ajzen, and Hrubes (2003) also combine cheap talk with the contingent valuation method involving referenda to investigate the WTP for a scholarship aimed at needy and deserving students. They remark that the ability of cheap talk to reduce hypothetical bias increases with the dollar amount related to the referendum. Both Lusk (2003) and Brown, Ajzen, and Hrubes (2003) suggest that future research is needed to better understand the relationship between cheap talk effectiveness, respondents' knowledge, and payment vehicle.

In conclusion, very few studies use either the contingent valuation method or conjoint analysis to estimate the impact of a new agricultural technology on farmers' welfare and most studies attempt to mitigate bias at the source with a careful design of the survey instrument. No new methods appear to exist for mitigating non-response bias and the bias resulting from random error process. However, various methods were proposed to mitigate hypothetical bias. Among all of them, cheap talk, which consists in explaining hypothetical bias so as to reduce its occurrence, is the most popular and the most subject to controversy. Many researchers concur that additional research is needed to improve the ability of cheap talk to mitigate hypothetical bias. There is also the learning design, a combination of hypothetical and non-hypothetical valuation methods, which appeared to have provided accurate results in only one study, and which has not been contested since.

Consumer Level Impact of New Technology

This section discusses how observed data- and perception-based methods have so far been used to estimate the consumer level impact of a novel product, more specifically of a novel Genetically Modified (GM) product.

There exist numerous studies which aim at estimating WTP for genetically modified foods, but they all involve perception-based methods and the majority is undertaken in non-African countries including the United States, and some European and Asian countries. Among these studies, contingent valuation is most popular; apart from contingent valuation, other valuation methods include choice modeling, experimental methods, and conjoint analysis. In most of these previous studies, consumers seem to be discounting GM food relative to its standard counterpart. In the very few studies where GM food is associated with a premium, consumers tend to believe that GM food provides food quality improvements (Noussair, Robin, and Ruffieux, 2001; Burton et al., 2001; Baker and Burnham, 2001 ; Chern et al., 2003; Bocaletti and Moro, 2000; Lusk, 2003; Huffman et al., 2003; Grimsrud, 2004; Sallie and Burton, 2003; Moon and Balasubramanian, 2003; Li Quan et al., 2002).

There is one study that aimed at estimating consumers' WTP for a novel non-GM food product in Africa. The study was undertaken by Kimenju, Morawetz and De Groote (2005) and involved various perceptions-based methodologies to estimate consumers' ex ante WTP for biofortified maize in Kenya. Maize biofortification would enhance the nutrient content of maize via post-harvest processing. The ex ante valuation methodologies include contingent valuation, choice experiment, and experimental auctions.

The authors compare results from the three methodologies with current market prices to conclude that experimental auctions provide most accurate results. Their results from the methodology involving experimental auctions implies that the average household in the Siaya district exhibits a premium of about 1.9 Kenyan shillings for 2 kilograms of yellow maize meal, contrary to the average household in Vihiga district who exhibits a discount of about 1.4 Kenyan Shillings. It is important to note that this result is appropriate for the specific period during which the survey took place, and is not representative of consumers' WTP in other periods. Food prices vary widely from one month to the next, sometimes from one week to the next. Therefore, estimated WTP via the methodology used by the authors is unlikely to be representative of WTP in other periods.

Moreover, the authors do not provide enough information on the procedures involved with contingent valuation and choice experiments, so that it is difficult to identify the potential sources for the differences observed between the results related to experimental auctions and the ones related to contingent valuation and choice experiment. Hypothetical bias might not be the only cause for these differences, as implied by the authors. It is actually very likely that the procedure involving choice experiment provided respondents with incentives for misrepresentation, so that the latter overestimated their true WTP for fortification. It is also likely that the authors introduced biases in the results by allowing respondents to discount fortification in experimental auctions and by preventing them from doing so with the experiments involving choice experiment.

Similarly, with contingent valuation, the authors state that a fortification premium of 20% above current prices is too high to be realistic, but they do not provide enough justification for their statement. Once again, other biases apart from hypothetical bias could explain the divergence between the results related to contingent valuation and the other methodologies: biases related to systematic error process and the ones resulting from sample non-response.

In conclusion, only perception-based methods have so far been used to estimate the consumer level ex ante impact of a novel product, even though both observed data- and perceptions-based methods could be used for such purpose. Perception-based methods are more popular with consumers because they involve less work and also because the consumer problem is usually assumed to be too simple to warrant an analysis involving observed data-based methods.

Conclusion

This study is the first one to assess both observed data- and perception-based methods as non-market valuation methods. Previous literature on non-market valuation methods never included observed data-based methods, and the previous literature where observed data-based methods were used for ex ante impact assessment never acknowledged these observed data-based methods as non-market valuation methods. Observed data-based methods include budgets, regression, mathematical programming, and simulation. Perceptions-based methods include the contingent valuation method, choice-based conjoint analysis and experimental methods.

Findings from this study suggest that both observed data-based and perception-based methodologies can be used to estimate the ex ante impact of a novel product on the welfare of producers and consumers. The findings also imply that the appropriate observed data-based method for farm level ex ante impact assessment of a new technology would involve a combination of simulation and mathematical programming. On the other hand, experimental methods are the preferable perception-based method for estimating the ex ante economic impact of a novel product on the welfare of an economic agent.

The review of literature shows that observed-data based methods and more specifically mathematical programming are more popular for estimating the ex ante farm-level economic impact of a new technology. On the other hand, perception-based methods are more popular for estimating the ex ante economic impact of a novel product for consumers.

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